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Modifying the X-Matrix to Capture the Joint Capability Architecture

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Abstract

The Department of Defense (DoD) manages programs of systems from concept through development to production with Joint Capability Areas (JCAs). JCAs are a standardized grouping of capabilities that enable DoD decision makers to allocate resources based on a programs contribution to joint operations. Additionally, the DoD has established Universal Joint Tasks (UJTs) to serve as a common language for describing functions a system performs across the four services. Similar to JCAs, a system performs one or more UJTs in support of the joint war fight. Although JCAs and UJTs are well described and understood by the joint community within the DoD, the DoD lacks a method for visualizing the links between program, JCAs, and UJTs at the enterprise level. Enterprise Architecting is an approach for analyzing an enterprise level system and developing candidate architectures for the enterprise to deliver value. Enterprise Architecture tools, specifically, the X-Matrix provides an opportunity for the DoD to visualize these links to ensure alignment of programs to JCAs and UJTs. Additionally, the X-Matrix enables DoD decision makers to understand potential gaps or unnecessary redundancies at the enterprise level. Given the current fiscal reality in the DoD, analysts must provide leaders with data based recommendations on systems to ensure that the DoD is being efficient with their limited resources. This modification of the X-Matrix enables the visualization of essential links between programs, the form of the enterprise, and the JCAs and UJTs, the function of the enterprise. It provides DoD leadership with a tool to visualize the impacts of resourcing decisions and potentially make better investments in programs to support the joint warfighter.

Kewords: Enterprise Architecture; X-Matrix; Joint Capability Areas

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1. Introduction

The Department of Defense (DoD) manages programs of systems from concept through development to production with Joint Capability Areas (JCAs). JCAs are a standardized grouping of capabilities that enable DoD decision makers to allocate resources based on a programs contribution to joint operations. Currently, nine JCAs span the range from Force Application, traditional war fighting tasks, to Corporate Management and Support, the business side of the DoD. As part of the Joint Capability Integration and Development System (JCIDS, every system the DoD acquires must support one or more of these JCAs in order for DoD leadership to deem them necessary to allocate resources towards. Additionally, the DoD has established Universal Joint Tasks (UJTs) to serve as a common language for describing functions a system performs across the four services. Similar to JCAs, a system performs one or more UJTs in support of the joint war fight. Although JCAs and UJTs are well described and understood by the joint community within the DoD, the DoD lacks a method for visualizing the links between program, JCAs, and UJTs at the enterprise level.

Enterprise Architecture tools, specifically, the X-Matrix provides an opportunity for the DoD to visualize these links to ensure alignment of programs to JCAs and UJTs. Additionally, the X-Matrix enables DoD decision makers to understand potential gaps or unnecessary redundancies at the enterprise level. Enterprise Architecting is an approach for analyzing an enterprise level system and developing candidate architectures for the enterprise to deliver value. The X-Matrix is a tool that enables enterprise architects to determine the alignment of an enterprise's objectives, metrics, processes, and stakeholder values. This tool captures the strength of the links between each of these variables and provides a visual tool for decision makers to understand the alignment of the enterprise.

In this modification of the X-Matrix, the tool enables DoD leaders to visualize the alignment of their programs to JCAs and UJTs. Additionally, it informs resourcing decisions made by DoD leadership by depicting the effects of cutting a program on JCAs, UJTs, and other programs. It captures the links between the programs of systems and the JCAs in one quadrant of the matrix and the links between the programs and the UJTs in the bottom left quadrant. The bottom right quadrant of the matrix is similar to a design structure matrix in that it captures the dependencies between programs. Finally, it captures documented links between JCAs and UJTs that DoD leaders can use to ensure a program supports a JCA based on its actual function. Given the current fiscal reality in the DoD, analysts must provide leaders with data based recommendations on systems to ensure that the DoD is being efficient with their limited resources. This modification of the X-Matrix enables the visualization of essential links between programs, the form of the enterprise, and the JCAs and UJTs, the function of the enterprise. It provides DoD leadership with a tool to visualize the impacts of resourcing decisions and potentially make better investments in programs to support the joint warfighter.

2. Literature Review

This section provides a summary of the literature related to the Joint Capability Areas, as well as a review of the literature for enterprise architecture. The review describes the history behind the JCAs, a detailed description of the areas, and the linkage to the JCIDS process. Additionally, the review describes the theory behind enterprise architecture and details the use of the X-matrix as a tool for visualizing and communicating the alignment of the enterprise.

2.1. Joint Capability Areas

The 2003 Joint Defense Capability Study first presented the concept of Joint Capability Areas as it proposed the DoD transition from a requirements based acquisition process to a capability based approach[1]. The study found that programs focused too narrowly on a single requirement for a single scenario and that throughout the process scope creep increased the cost and schedule of a program to an unacceptable level. To prevent this and to focus more broadly on capabilities that could be applied to a range of military operations, the department changed from to a capability based process to acquire new programs.[1] A subsequent study in 2005 defined the initial set of JCAs, which included 21 initial Tier 1 JCAs and over a hundred proposed Tier 2 capabilities.[2] Joint Capability areas are logical groupings of DoD capabilities that are used for capability analysis, strategy development, investment

decision making, capability portfolio management, and capabilities-based force development. The DoD defines a capability as "The ability to achieve a desired effect under specified standards and conditions through a combination of means and ways across doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTMLPF) to perform a set of tasks to execute a specified course of action".[3] Between 2007 and 2008 the DoD refined the JCAs and reduced the Tier 1 JCAs to the nine current JCAs and broke them down to the Tier 3 level. Currently, the nine JCAs include Force Support, Battlespace Awareness, Force Application, Logistics, Command and Control, Net-Centric, Protection, Building Partnerships, and Corporate Management and Support .[4]

The JCAs provide a significant contribution to the JCIDS process as they categorize capabilities into defined areas and support decision making and resource allocation. The JCIDS process exists to support the Chairman of the Joint Chiefs of Staff in identifying, validating, and approving capability requirements across the Joint Force.[5] The methodology and X-matrix this paper presents supports this responsibility by providing a visualization tool to capture how programs provide the department with the capabilities necessary to execute operations. Additionally, the tool could potential assist in identifying capability gaps that exist. The DoD has established Functional Capability Boards (FCBs) that are aligned with the different capability areas. One of their functions is to identify capability gaps through the use of capability bases assessments.[6] However, they lack a tool visualize their entire portfolio to identify gaps or redundancies at the portfolio level. This is where the X-Matrix presents an opportunity to determine the alignment of the programs to the established JCAs for the DoD.

2.2. Enterprise Architecture

Enterprise Architecture is an emerging field that applies holistic thinking to the design of enterprises as systems. Nightingale and Rhodes initially described Enterprise Architecture as "a new strategic approach which takes a systems perspective, viewing the entire enterprise as a holistic system encompassing multiple views such as organization view, process view, knowledge view, and enabling information technology view in an integrated framework".[7] In this work, they view enterprises as complex, integrated systems that are inseparable from their environment. Because of these interdependencies, an architect must view enterprise systems holistically and optimize at the system level, not in a traditional silo manner. To optimize the entire system, a holistic view of the enterprise through several lenses is required. Over the last several years, Nightingale and Rhodes have refined the views to include: strategy, policy/external factors, organization, process, knowledge, information, product, and services.[8]

An essential element of understanding the enterprise architecture reference framework is specifying how the framework defines each term. Nightingale and Rhodes have refined their definition of Enterprise Architecture as "applying holistic thinking to conceptually design, evaluate, and select a preferred structure for a future state enterprise to realize its value proposition and desired behaviors".[9] In addition to understanding the definition of Enterprise Architecture, one must understand the terms "enterprise" and "architecture".

An enterprise is "one or more persons or organizations that have related activities, unified operation or common control, and a common business purpose" .[10] Rouse proposed thinking of an enterprise as a system or system of systems and defined an enterprise as "a goal-directed organization of resources—human, information, financial, and physical—and activities, usually of significant operational scope, complication, risk, and duration" .[11] He goes on to state that generally enterprise share the same goals of growth, value, focus, change, future, knowledge, and time. Additionally, he proposes that models and scientific tools can evaluate the performance of an enterprises' as-is and to-be states.[11] Nightingale and Rhodes define an enterprise as "complex, highly integrated systems comprised of processes, organizations, information, and supporting technologies, with multifaceted interdependencies and interrelationships across their boundaries".[7] Although these are all very broad definitions of enterprises, they provide a common frame of reference for what is meant by "enterprise".

Maier and Rechtin describe a system's architecture as a description of "whatever aspects of physical structure, behavior, cost, human organization, or other elements are needed to clarify the client's priorities".[12] In their view, an architect is an agent of the client who works with the client and the builder on problem and solution definition to generate system requirements. Also, architecture is more an art than a hard science as the architect must rely on experience and heuristics, in addition to science and standards, to develop solutions that address non-analytic, immeasurable, or less understood problems.[12] Enterprise Architecting fits into this category of architecting, in which,

the architect is dealing with complex, sometimes very ambiguous problems, where the use of traditional analytic tools may not be appropriate. Standards and frameworks for architecture, such as the Zachman Framework, or Department of Defense Architecture Framework (DoDAF), all have their applications; however, these frameworks are separate from the reference framework Enterprise Architecture used in this thesis to analyze enterprise level systems.[7] Additionally, Enterprise Architecture differs from enterprise engineering in that in architecture the architect analyzes and designs the enterprise for value delivery. Whereas, in engineering the engineering systems drive the structure and function of the organization and the enterprise culture and structure can impact the system design .[13]

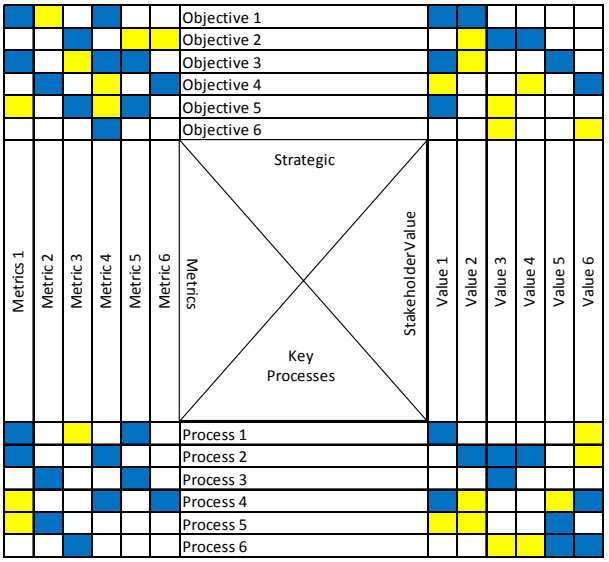

Fig. 1. X-Matrix [14]

The Enterprise Strategic Analysis and Transition (ESAT) Guide provides a method to determine the alignment of an enterprise's objectives, metrics, processes, and stakeholder values.[14] Figure 1 presents the X-Matrix, a tool to visualize the alignment of these aspects of the enterprise by assigning a strong or weak alignment between the different aspects of the enterprise. The upper left quadrant of the X-Matrix shows if the metrics are accurately evaluating the performance of the enterprise in relationship to the strategic objectives. The lower right quadrant evaluates the ability of the enterprise's metrics to accurately measure the key processes. The upper left quadrant shows how well the enterprise has aligned their strategic objectives with the stakeholder values. Finally, the lower left quadrant evaluates the alignment of the enterprise processes with the stakeholder value.

3. Methodology

The focus of this paper is modifying the X-matrix to capture the capability architecture of the DoD to visualize the alignment of programs to capability areas as well as tasks. Figure 2 presents the modified X-matrix. In the upper right quadrant, the matrix captures the links between programs and joint capability areas. The lower right quadrant captures the program-to-program dependencies that are essential to determining how changes to one program could have second and third order effects within the enterprise. The upper left quadrant captures linkages between the UJTs and the capability areas that they support. Finally, the lower left quadrant identifies the specific tasks that each program executes. For the purpose of this paper, the links identified are logical, but may not represent the actual linkages for these systems, nor is the matrix an all-inclusive listing of the DoD programs and capabilities.

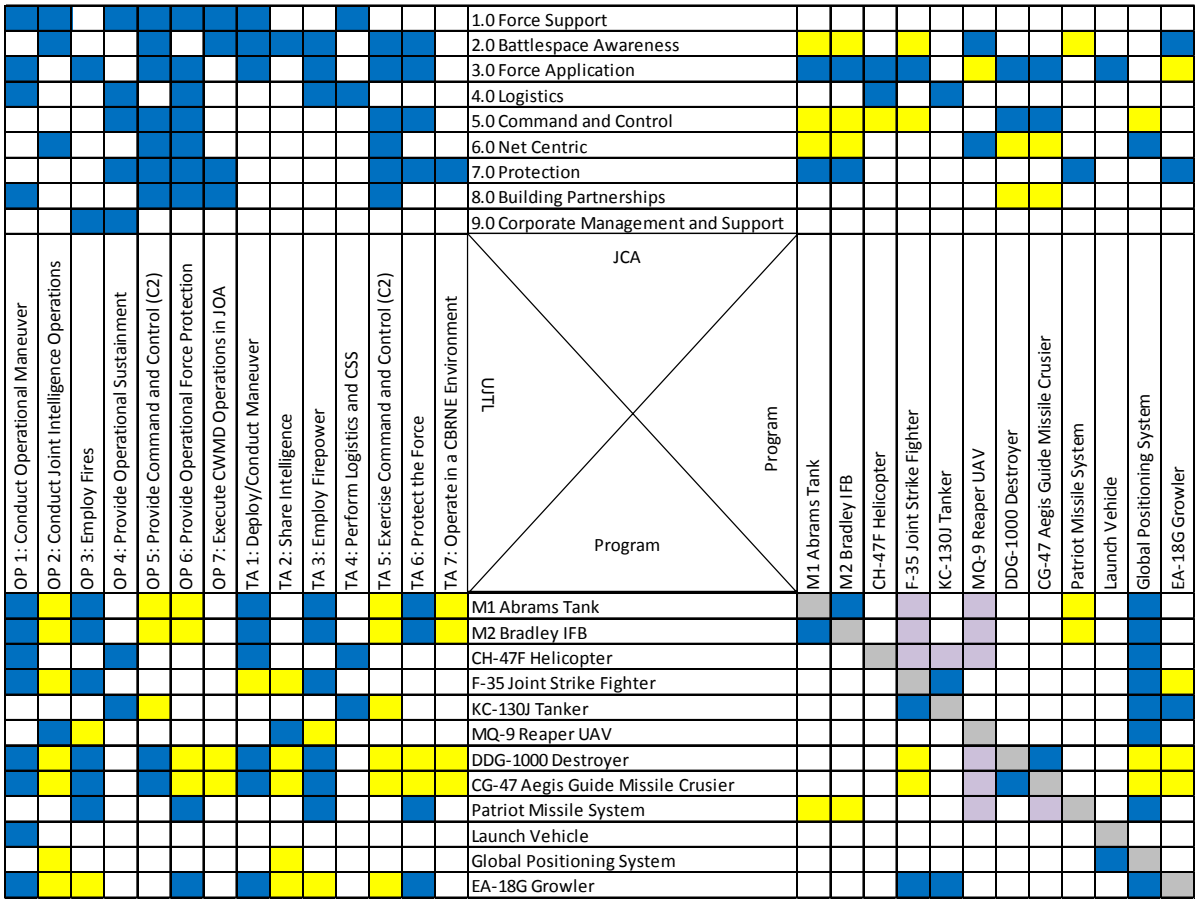

Fig. 2. Modified X-Matrix

3.1. Program to Capability Area Links

As part of the JCIDS process implementation, the DoD changed from a requirements based program development process to a capability based process. As such, each program is required to support at least one of the JCAs and the supporting JCIDS documents capture these relationships. Additionally, the documents may specify whether the system supports a JCA as a primary or secondary capability. So, within the X-matrix the DoD can capture both the relationship as well as the importance of the relationship. Figure 3 presents an example of this quadrant and shows how several programs support the various JCAs in a one to many relationship. This visualization enables DoD leadership to quickly identify potential gaps in capabilities as well redundancies which analysts could further research to determine if they are necessary or unnecessary redundancies. In this example, there are currently no systems provide the Force Support or Corporate Management and Support capability. Additionally, two systems provide building partnership capability only as their secondary capability. So, there are potential gaps in these areas. Again, this is only a sub-set of the DoD programs and it is likely that other programs provide these capabilities. But as the matrix decomposes to lower tiered JCAs, potential gaps could exist even after capturing all programs across the department.

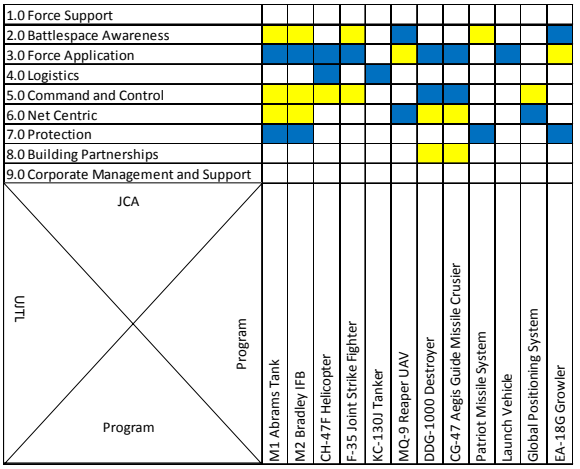

Fig. 3. Modified X-Matrix (Program to JCA)

3.2. Program to Program Links

Nightingale, Stanke, and Bryan's X-Matrix captures the stakeholder to process links in the lower right quadrant of the X-Matrix .[14] In their version, they do not explicitly capture interdependencies within any of the four attributes they capture. However, for DoD programs, the interdependencies between programs is extremely important and should be captured at the enterprise level. This enables decision makers and DoD leadership to identify how programs are dependent upon one another and could identify potential second and third order impacts of resourcing decisions. To capture this aspect of the capability architecture the modified X-Matrix utilizes the lower right quadrant similar to a Design Structure Matrix (DSM). A DSM is a tool used for designing, developing, and managing complex systems by capturing the interdependencies of their components in a matrix .[15]

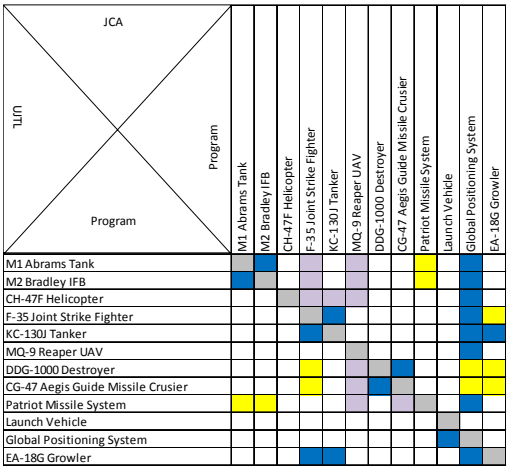

Fig. 4. Modified X-Matrix (Program to Program)

Figure 4 presents an example of how this tool captures the program-to-program dependencies. Additionally, the matrix could capture the direction of dependency through the use of the upper and lower diagonals. For example, in the figure the M1 Abrams depends on the Global Position System; however, the Global Position System does not depend on any other systems except the launch system.

3.3. JCA to UJTL Links

The upper left quadrant of the X-Matrix presents the linkages between the JCAs and the Universal Joint Task Lists (UJTL). The UJTL provides a list of tasks, or warfighting functions, that a program or organization executes to support the joint warfighting mission .[16] The UJTL is divided into four major areas, Strategic National, Strategic Theater, Operational, and Tactical. These tasks are further decomposed into various levels to provide greater fidelity on the tasks. Additionally, the joint staff has identified how each task supports the capability areas as part of the capability development process. Figure 5 presents a portion of the UJTL links to the JCAs. When combined with the program to JCA and program to UJTL links the DoD leadership is able to determine the alignment of the programs to the JCAs and UJTLs to ensure that they are accurately capturing the supported capability based on the tasks the program performs.

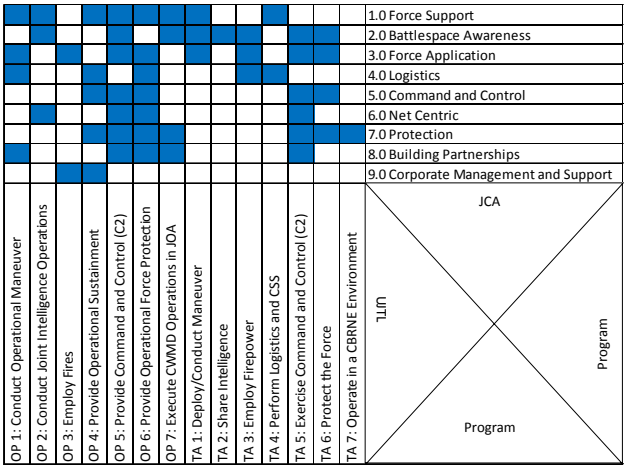

Fig. 5. Modified X-Matrix (JCA to UJTL)

3.4. Program to UJTL Links

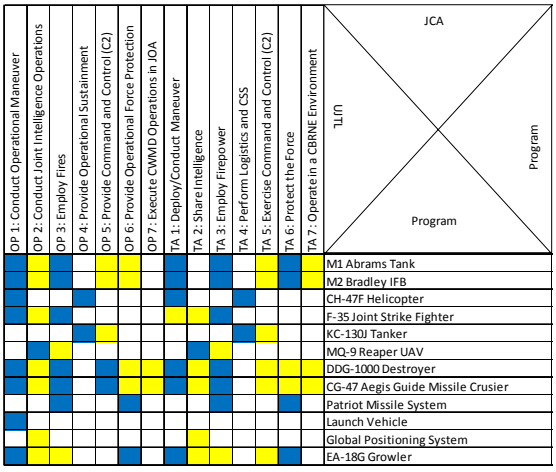

Fig. 6. Modified X-Matrix (Program to UJTL)

The final quadrant of the modified X-Matrix presents the linkages between the programs and the UJTL tasks. Again, these can be designated as primary or secondary relationships. The JCIDS documents specified the

relationships between the programs and the UJTL tasks. Similar to the JCA links, the links between the programs and UJTLs enable leadership to visualize redundancies and gaps in UJTL tasks.

4. Conclusion

This paper presented a modification of the X-Matrix developed by Nightingale, Stanke, and Bryan in their Enterprise Strategic Analysis and Transformation Guide. The original version of the X-Matrix provided a tool to visualize the alignment of the enterprise based on their strategic objectives, stakeholder values, processes, and metrics. This modification adapts their original X-Matrix to provide a tool for the DoD to visualize capabilities across the department. It examines the links between programs and capability areas, program-to-program interdependencies, program to task, and finally tasks to capabilities.

As more detail is added to the X-Matrix, the tool will become more useful to DoD leadership as they make resourcing and capability decisions in the future. As the tool matures and more detail is added at the lower level JCAs and UJTLs the department may identify capability gaps given the current systems. This paper provides a basis for future work in developing the enterprise level architecture for the DoD as it examines capability areas, programs, and resourcing. As the analysis matures, it may be possible to incorporate additional information provided in the JCIDS documents, to include DoDAF products for individual programs. Eventually, it may be possible to synthesize DoDAF products to capture the data required for a detailed X-Matrix for the DoD. This will enable the DoD leadership to visualize the relationships within the capability enterprise architecture of the DoD. Additionally, this work provides the basis for potentially exploring how network analysis tools and methods could be used to visualize and analyze the relationships between programs.

References

1. Joint Chiefs of Staff, “Joint Defense Capability Study: Improving DoD Strategic Planning, Resourcing and Execution to Satisfy Joint Capabilities”, Department of Defense, Washington, D.C., January 2004
2. Joint Chiefs of Staff, “Joint Force Capabilities Assessment”, Department of Defense, Washington, D.C., 2005
3. Department of Defense, “Department of Defense Directive 7045.20”, Department of Defense, Washington, D.C., September 25, 2008
4. Office of the Secreatary of Defense, “Memorandum for the Vice Chairman of the Joint Chiefs of Staff: Joint Capability Area (JCA) 2010 Refinement”, Department of Defense, Washington, D.C., April 8, 2011
5. Joint Chiefs of Staff, “CJCS Instruction 3170.01H: Joint Capabilities Integration and Development System,” Department of Defense, Washington, D.C., January 10, 2012
6. Joint Chiefs of Staff, “Capability Based Assessment (CBA) User Guide”, Department of Defense, Washington, D.C., December, 2006
7. Nightingale, Deborah, and Donna Rhodes, "Enterprise Systems Architecting: Emerging Art and Science within Engineering Systems", MIT Engineering Systems Symposium, Massachusetts Institute of Technology, Cambridge, MA, 2004
8. Rhodes, Donna, Adam Ross, and Deborah Nightingale, "Architecting the System of Systems Enterprise: Enabling Constructs and Methods from the Field of Engineering Systems", SysCon2009 – IEEE International Systems Conference, IEEE, Vancouver, Canada, 2009
9. Nightingale, Deborah, and Donna Rhodes, "ESD.38J Enterprise Architecture", Course Notes, Massachusetts Institute of Technology, Cambridge, MA, 2007
10. Black's Law Dictionary, Black's Law Dictionary, 9th Edition, Edited by Brian Garner, West Group, St. Paul, MN, 2009\
11. Rouse, William, "Enterprises as Systems: Essential Challenges and Approaches to Transformation", Georgia Institute of Technology, Atlanta, GA, February 12, 2005
12. Maier, Mark, and Eberhardt Rechtin, The Art of Systems Architecting, Second Edition, CRC Press, New York, NY, 2002
13. Allen, Thomas, Deborah Nightingale, and Earl Murman, "Engineering Systems: An Enterprise Perspective", MIT Engineering Systems Division, Cambridge, MA, March 31, 2004
14. Nightingale, Deborah, Alexis Stanke, and F. Terry Bryan, "Enterprise Strategic Analysis and Transformation Guide", Vol. 2.0, MIT Lean Advancement Initiative, Cambridge, MA, September 2008
15. Eppinger, Steven D. and Tyson R. Browning, “Design Structure Matrix Methods and Applications”, Cambridge, MA: The MIT Press, May 2012
16. Joint Chiefs of Staff, “UJTL Task Development Tool”, https://utdt.js.mil/, 1 April 2010